

Near Space Environments: Tethering Systems

Nolan R. Lucht

Kennedy Space Center

Major: Aerospace Engineering

Program: KSC-FO Summer

Date: 29-07-2013

Nolan Lucht

Nicole Dawkins

Summer Internship

29 July 2013

Near Space Environments: Tethering Systems

1. Abstract

Near Space Environments, the Rocket University (Rocket U) program dealing with high altitude balloons carrying payloads into the upper earth atmosphere is the field of my project. The tethering from balloon to payload is the specific system I am responsible for. The tethering system includes, the lines that tie the payload to the balloon, as well as, lines that connect payloads together, if they are needed, as well as how to sever the tether to release payloads from the balloon. My objective is to design a tethering system that will carry a payload to any desired altitude and then sever by command at any given point during flight.

2. Obstacles

The obstacles I faced to achieve success for this project was numerous and had to be overcome. Our first obstacle was how to select the correct tether, due to restrictions imposed by the Federal Aviation Administration (FAA), we could not use a tether that could survive an impact of more than 50#.

The next obstacle was not only did the tether need to be strong enough to support a payload through ascent above 60,000 ft, it also had to separate, on

command, from the balloon via a “burnbox.” This meant the tether had to be strong enough to lift the payload, weak enough to meet the FAA guidelines and frangible enough to allow separation on command.

Other than what the tether was made of, there was also the “how” it was configured between the payload and the balloon. Seemingly simple, the tether configuration was one of the greatest challenges on this project. The team was required to have a tether configuration of which there would be no doubt of the parachute opening in any situation, as well as, never tangle due to the large amounts of twisting experienced on ascent, to the point of inhibiting the payload to separate from the balloon.

3. Tether

The tether material began as a twisted cotton rope that was used for a number of balloon launches before my participation in the project. While meeting the requirements of being able to burn and not withstand more than 50# of impact, the cotton was unable to support the payload during ascent, as it snapped at about 70,000 ft. This failure illustrated the need to switch to a new material of tether for our balloons.

My first action on this project was to find this new material for the tether, after much market research and study I decided upon, Spectra, a high strength-low stretch material commonly used for fishing line. This, Spectra, had a great strength-to-weight ratio that also melted at a low temperature compared to the cotton. This line was also sold in pound test measurements which would allow us to purchase tether line that would comply with the FAA guidelines just by looking at the strength the manufacturer

provided. However, in balloon lab 6a, the tether snapped on the balloon prior to liftoff, setting free the balloon and in doing so, scrubbing the launch. Once again with more information the team was tasked with finding a new tether material that was robust enough to handle the payload but frangible enough to burn and meet the FAA guidelines. The final tether material decided on was 150 pound test braided Nylon. We chose this as our tether due to a variety of reasons: first, the rope was very robust and was rated to 150# yet it could still be broken with an impact of 50#, insuring we met the FAA guidelines, second, the relatively low melting point of Nylon insured us we could separate from the payload on command using the "Burnbox," and finally, this type of rope had been used in the high altitude ballooning community for many years showing us its reliability as well as giving us quantities of data to research, allowing us to more reasonably assure mission success.

4. Burnbox

The "Burnbox" is somewhat of a new idea in the high altitude ballooning world. Separating your payload from the lifting vehicle has always been done but in the world of balloons, most teams are content with waiting for the eventual burst of the balloon to return their payload to the ground. The Rocket U balloon team did not have the luxury of avoiding the implementation of a separation mechanism. For various reasons the "Burnbox" was critical for mission assurance. First, the FAA guidelines state if the balloon is carrying a payload of more than 6lbs, you must have a separation mechanism redundant to the balloon burst, second, the balloon team was carrying experiments that would need to be dropped at specific altitudes in order to attain data, finally, NASA safety and range safety both put a high value on being able to control when and where

the payload is released, not only to control where the payload will land but also to include a failsafe in the case of the balloon causing unforeseen danger. This all led to the creation of Rocket U's "Burnbox," the way it works is running one end of the tether through a coil of highly resistive NiChrome wire and then tied to an internal anchor. During the flight, when the team sends a command to the payload to fire the burn, a current is pushed through the wire, causing it to heat to an excess of 450 degrees F thus burning through the rope and releasing the payload. The "Burnbox" went through various iterations, improving on its design by making it more robust and eliminating failure points; such as, moving the box closer to the payload itself as to reduce the length of the wires leading from the payload to the box, therefore mitigating the risk of failure due to a wire lead being pulled free. The final "Burnbox" design allows for easier access for the tether as well as mitigates the risk of the coil being ripped free of the electrical leads. The box is also tied directly to the payload to insure the leads from the avionics payload to the box cannot be pulled loose.

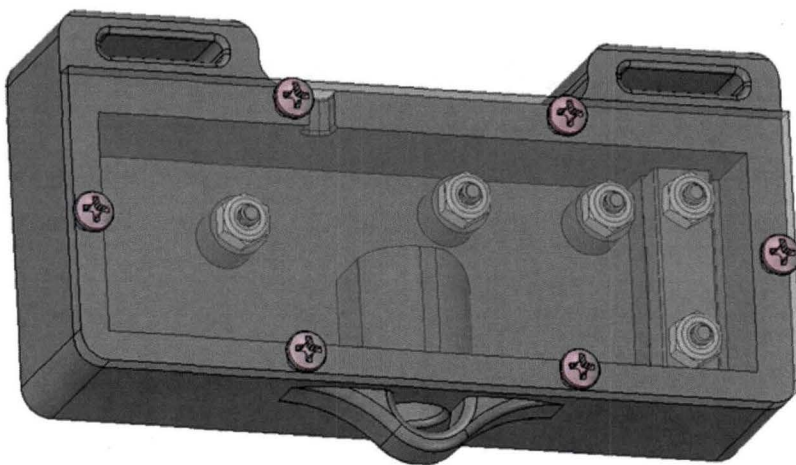


Figure 1. *Final Burnbox design. Tether line feeds through the bottom and tie off at the anchor post to the right (tinged in green).*

5. Balloon Lab 6

Rocket U: Near Space Sciences-Balloon Lab 6 is a series of balloon flights with the goal of testing and verifying tether and “Burnbox” design and operations. These flights were primarily my project for this internship. Being in charge of tether operations, I dealt with the selection of tether material, insuring load bearing as well as burnability, also the configuration of how it was rigged for flight.

5a. Lab 6a

Balloon lab 6a was the first launch of the summer. The tethering was set up using three independent lines of 20# Spectra cord, giving us added redundancy. This line was tied directly from “Burnbox” to the top of the parachute then clipped to the

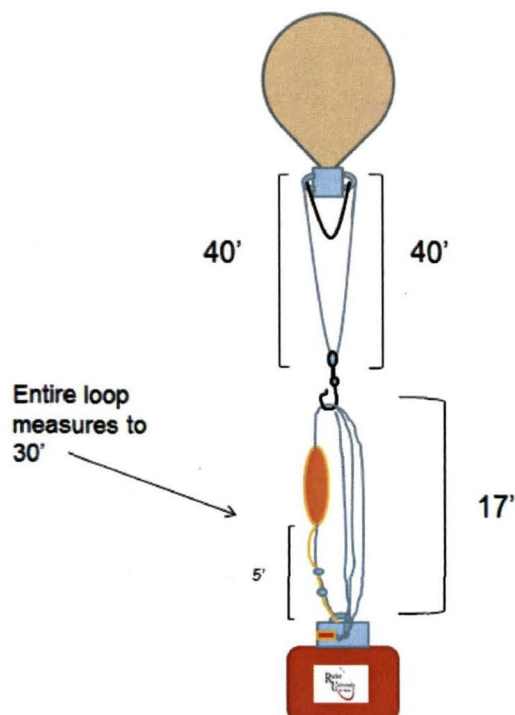


Figure 2. 6a tether configuration

balloon. As this configuration flew, it became evident to the team that the tether became tangled when the burn command was sent to the avionics without the payload separating from the balloon. The payload eventually fell free from the balloon 30,000 ft after the command was sent, eventually landing the payload miles off of our targeted landing point. Upon retrieval it was evident that the burn was successful but due to twisting experienced on ascent the three independent lines became

tangled and did not release when the line was separated. This showed us a burn success but no success in release, which became the goal for the next launch.

5b. Lab 6b

6b was the last flight in Balloon Lab 6, the focus of this flight was the same as before, to lift the payload to a target height, separate via command, then land in predicted drop zone. This balloon flew a new 150# Nylon line allowing the team to reconfigure our tethering system to fly only one line. Switching to a single tether line

solved the failure mode of having the tether tangle and prevent payload separation. Along with the reduction to a single tether, the line now runs through the opening in the parachute, taking the parachute out of the load line further mitigating the possibility of tangling. The balloon was launched successfully with the new tether and tether configuration holding through the entire ascent then was severed upon command with the payload separating from the balloon. The payload followed the predicted descent path accurately, falling within 10 ft of the recovery team. With all mission requirements met, Balloon Lab 6b was a resounding success, qualifying our tethering and separation systems.



Figure 3. 6b tether configuration

6. Conclusion

My project of launching a payload on a high altitude balloon and meeting various objectives during the flight was a success. With Balloon Lab 6b successfully verifying all of our balloon systems, the Rocket U: Near Space Sciences now has a ready-to-fly system in place to accept experiments and payloads with a confidence for success. Beginning with researching and reevaluating the choice of tether lines that met our mission specific criteria, finally culminating in the configuration of this tether with its concurrence not only with NASA and KSC safety, but also the FAA guidelines for balloon flight, this project took large amounts of research and collaboration with other NASA centers and commercial entities. The culmination of this data has resulted in the current con-ops of the Near Space Sciences Balloon Labs and will be a baseline system for many launches to come.